A Research Proposal for the Thesis titled

A study of fire toxicity of materials used in finishing of residential interior space and enhancing life safety of occupants

Submitted for the award of Degree of Doctor of Philosophy

By

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(November, 2024)

1. Introduction

India is among the nations with highest rates of accidents worldwide, and leaving aside risk from the forces of nature, fire accidents kill many every year. In 2022, a total of 7566 major fire accidents took place killing 7435 persons. The National Crime Records Bureau (NCRB) reported that 53.5 % of deaths occurred in residential/dwelling buildings in 2022. In recent years, we see a steady rise in fire incidents in urban population, not only because of population density but also due to abundant use of flammable and toxic interior materials. There have been huge losses reported for property and structural damages along with human lives.

A major step taken for risk reduction is fire risk assessment through a process of identification and evaluation of combustible hazards present in buildings in order to take corrective actions. The chemical reaction responsible for a fire to start, involves three essential components: A Combustible or a flammable material; the right amount of Oxygen and a source of heat. For a fire to sustain it requires a rapid rate of oxidation which leads to a chain reaction. The absence of any of these components shall deter the fire from burning.

As per the reports published by National Institute of Disaster Management in 2020, the frequency of fire accidents has grown to be a major source of distress for the entire world, without any disparity between the low income and high-income countries. As per the report "International Association of Fire and Rescue Services" claims that, 3.5 million fire events were recorded annually on an average from 2013 to 2017. According to the 2016 World Health Organization (WHO) estimates, there were approximately over 300 deaths annually which were attributed to fire, heating and hot chemicals in 71 countries (Centre of Fire Statistics, 2019). In 2017, a record number of 1.3 billion fire incidents were documented in the United States of America alone. Thereafter, Italy (Centre of Fire Statistics 2019), with 0.33 billion and then France with 0.31 billion fire breakouts, respectively (as per the 2019 statistics). Additionally, a $23 billion worth of property was recorded to have been damaged (Evarts 2018). Another study states that Russia saw 7,816 fatalities and 9,355 injuries in the same year, whereas only 3,400 fatalities were reported in US during the same year, that is only one death for every one lakh people. Even though there have been a large number of fire outbreaks and significant property damage, the low death rate indicates that risk assessment and preparatory steps were implemented by the country. This demonstrates how readiness measures can stop fire accidents from becoming a catastrophe. (National Institute of Disaster Management, 2020).

India is a country with varied climatic conditions. The soaring temperatures during the hot and dry summer months witness fire outbreaks as one of the most recurrently occurring accident. The rapid urbanization in the country has increased occurrence of fire incidents exponentially. In urban areas the presence of industries in the vicinity have enhanced vulnerability of the population to fire accidents. It has been reported that every 5^{th} death in India is attributed to fire accidents. Between 2018-2022 on an average 4.07 lakh deaths have occurred due to accidents by causes other than forces of nature and 8,000 deaths per year have been due to fire incidents. (National Crime Records Bureau, 2018)

One of India's deadliest tragedies, the Uphaar Cinema fire, occurred on June 13, 1997, in New Delhi, killing 59 people and injuring 103 wherein, a transformer fire ignited and spread to parked cars, creating toxic smoke that filled the cinema. As smoke traveled through stairways and air ducts, it caused mass asphyxiation among the audience, who were unable to evacuate in time. The release of carbon monoxide and other gases from burning materials contributed to the high fatalities. Similarly, there have been many more fire accidents like Arpit Palace Hotel in Delhi, TRP Game zone in Rajkot, Takshila Classes in Surat, etc. where the interior finishing materials contributed heavily to human vulnerability against toxic gases produced by burning materials.

To investigate a fire incident, it is of utmost importance to examine the origin of the fire and the flammability of the combustible materials. (Babrauskas 2014). The starting point of all fires is ignition. For a fire investigator to determine the cause it is necessary to understand the burning process of a particular combustible material. Another important aspect is the amount of heat required for that material to ignite and burn. To answer these questions, it is essential to test the materials for understanding their ignition and burning properties which shall then aid in constructing a theory accurately. Conversely, the fire investigators need to have knowledge about the ignition characteristics of materials subject to burning in an enclosed interior space so as to create spaces that could reduce the possibility of potential fire hazards.

As interior designers and architects it is pertinent to study the evaluation of fire load capacities as enumerated in the National Building Code (revised) and the yield of toxic gases released from finishing materials used for surface decoration and furniture installations to understand the vulnerability of people in high occupancy buildings.

Toxic smoke produced upon burning and combustion of inflammable materials used for interior space design is rendered as highly dangerous for human life. Inhaling these toxic smoke/ gases can lead to death and injuries during a fire. Toxicity in smoke rises rapidly when there is no ventilation for the fire (Stec 2017). For example, furniture manufacturers use bromine in the flame-retardant coating on furniture products, which is highly dangerous when converted into vapors on burning. (Richard 2018) It releases harmful and toxic gases such as Carbon Monoxide (CO) and Hydrogen Cyanide (HCN) which are highly deleterious for human life. (Buchanan and Abu 2017), (Brushlinsky et al. 2017). Carbon Monoxide is created when materials do not undergo complete combustion, Hydrogen Cyanide is created when plastic materials burn, and Phosgene Gas is created when interior finishes that contain vinyl burn. These gases when inhaled, lead to asphyxiation in occupants trapped inside. Apart from burns, inhalation of these toxic smoke/ gases is highly responsible for death during fire accidents.

Finishing materials offer a seamless and aesthetic appearance to the interior spaces. These materials in the advent of fire become fuel to the chemical process of combustion which upon release of toxic gases could prove to be fatal for life safety of occupants trapped inside. Therefore, a careful examination and selection of interior finishing materials is an important aspect of designing spaces which could enhance the safety of occupants in buildings.

Finally, it is equally important to offer guidelines to Architects and Interior Designers to make better & safe choices of Interior finishing materials to reduce the Vulnerability & Risk to not only the occupants but the Firefighters too. Absence of such ability will be highly disastrous for our nation and economy.

Key words: Hazardous materials, Interior Finishes, Fire Toxicity, Burning, Life Safety, Risk Assessment.

2. Significance/Importance of Study

Interior finishes are essential in transforming a building's interior from a basic structure into an aesthetically pleasing environment. Research indicates that interior finishing materials must fulfill fundamental functional requirements, such as safety and fire resistance, for protecting the health and welfare of the inhabitants. (Yanga et al. 2016), (Kodur et al. 2020). The National Building Code emphasizes the importance of managing fire load, which refers to the potential fire intensity based on the materials present in a space (National Building Code of India 2016). Today, designers have access to a wide array of interior finishes made from both natural and synthetic materials. While these options can enhance visual appeal, they may also pose

significant risks to occupant safety due to their susceptibility to ignition and combustion. When such materials burn, they release hazardous toxic smoke and gases that can obstruct safe evacuation by reducing visibility and incapacitating individuals through prolonged exposure (Nelson 1998). This has unfortunately contributed to a high number of fire- related fatalities, primarily due to asphyxiation and burns. This study aims to draw conclusions about the toxic hazards and life-threatening risks associated with the combustion of flammable finishing materials used in enclosed interior spaces.

3. Literature Review

The literature study, reviews case studies based on the enquiry questions formulated during the initial research, in the domain area. It seeks to offer a comprehensive understanding regarding current challenges and recent research conducted by authors in the domain of fire hazards posed by interior finishing materials and identify the research gap to formulate the research problem for further study.

3.1 Research Questions for Literature Review

3.1.1 What are the potential risks posed by combustible interior finishing materials during a fire accident?

1. (Baker and Jones 2021) in their study titled, "Fire performance of combustible materials in residential settings: A review of risks and implications" discuss the fire performance of various combustible interior materials. The study highlights that materials like untreated wood and certain textiles can significantly accelerate flame spread, increasing the risk of structural failure and occupant exposure.
2. (Chen and Zhang 2022) assess the fire risks of modern interior finishing materials through a case study approach. The authors assess multiple case studies where modern combustible materials contributed to rapid fire spread. The key findings emphasize the need for enhanced testing and regulation of these materials to mitigate risks in residential and commercial environments.
3. (García and Mendez 2020) study the impact of flammability on fire dynamics in interior spaces. This study examines how different combustible materials influence fire dynamics within interior spaces. The findings indicate that materials with high flammability not only

facilitate faster fire spread but also exacerbate smoke production, increasing dangers for occupants.

4. (Koch and Dobbins 2023) analyse the role of combustible finishes in fire incidents. They conduct a longitudinal study analysing fire incidents linked to combustible interior finishes. Their results reveal a clear correlation between the use of such materials and the severity of fire events, underscoring the urgent need for improved safety standards.
5. (Liu and Sun 2021) Combustible materials in interior design: Risks and recommendations. Materials Today: Proceedings, 45, 6340-6346. This research identifies the risks posed by commonly used combustible materials in interior design, suggesting that certain materials contribute disproportionately to fire load and smoke toxicity, necessitating careful selection in design practices.
6. (Niemann and Hall 2020) assess the fire behavior of interior finishes. The authors evaluate the fire behavior of various interior finishing materials, focusing on the ignition and spread rates. They conclude that inadequate safety protocols can significantly increase the risk of fire incidents in buildings with high concentrations of combustible materials.
7. (Rogers and Lee 2022) evaluate the toxic smoke production from burning combustible interior materials. This study investigates the toxic smoke produced from common combustible materials, revealing that materials such as certain plastics and textiles release highly toxic gases during combustion, posing health risks to occupants and first responders.
8. (Smith and Chen 2023) focus risk assessment in high-rise buildings, assessing how combustible finishing materials can increase fire risks due to vertical flame spread. They advocate for stricter regulations and material testing to improve safety in these structures.
9. (Thompson and Peters 2021) conduct a comparative analysis of traditional and modern practices. This comparative analysis discusses how traditional building materials can sometimes offer better fire resistance than modern alternatives, which are often more combustible. The authors suggest a reevaluation of material selection criteria in building codes.
10. (Williams et al. 2023) have reviewed the flammability tests and risk assessments for interior materials. In this critical review, the authors analyze existing flammability tests and their effectiveness in predicting real-world fire risks associated with interior materials. They call for standardization in testing methods to better assess the risks of combustible materials in fires.

3.1.2 What is the impact of smoke / toxic gases on humans, released by finishing materials during burning?

1. In their own research, (Alarie 1985), (Purser 1988) and (Hartzell 1996) state that during 1970's the furniture industry saw an increasing use of synthetic polymers, which made it essential to check them for toxicity during a fire. Upon testing the lethal effects of smoke from synthetic materials were determined, it was also found that Carbon Monoxide (CO) is not the only major toxicant in fire smoke but Hydrogen Cyanide (HCN) and Hydrogen Chloride (HCl) were also found to be critical, and their presence depends on the chemical composition of the material burning.

1. (Hu 2017) investigated the influence of wind on pool fires and the change in dynamics of fire such as heating, flaming, blazing and radiation due to the flow of wind. The findings offer crucial information on growth of fire in the interior spaces and the spread of smoke throughout the city scape. Recently, there have been many studies conducted by various authors studying the impact of wind on fire growth and spread.
2. (Tohidi and Kaye 2016) evaluated how wind affects flame spread over solid surfaces, revealing its significant impact on fire behaviour, particularly in the presence of wind-driven fires, such as wild fires or structural fires. (Tohidi et al. 2017) also contributed to the body of research on wind effects on fire behaviour, emphasizing how wind can alter flame characteristics and fire progression.
3. (Tang et al. 2017) investigate how wind can impact the growth and spread of fires, with particular emphasis on "intermittent flame extensions". According to their experiments, wind can impact the stability and strength of the fire, causing disturbance especially in the wild areas such as forests and buildings.
4. The dynamics of "flame propagation" have been examined by (De Ris 1969) offering theoretical understanding regarding the co-relation between fuel, flames and environment. Their ground breaking research enhances the understanding of "flame propagation" and is considered as an important guiding point for researchers in this discipline.
5. (Sirignano 1972) have reviewed various studies examining the growth of fire on fuels. This study underlines the intricacies of the combustion process of fuels, in both solid and liquid state, assessing their favorable and the unfavorable factors.
6. (Oyama et al. 2005) conducted studies to understand the role of orientation in spread of fire over a particular material. The position of the material for testing were in upward slope, downward slope and flat horizontal which gave results showing the impact of direction and position on growth and spread of fire. The studies were conducted on

"PMMA (polymethyl methacrylate)" samples, a type of plastic placed in various positions.

7. (Wakefield 2010) has reviewed the health hazards associated with toxic chemicals in the smoke produced as a result of incomplete and complete combustion. The study examines the dangers and risks for occupants when they are exposed to these toxicants in smoke.
8. (Sumi and Tsuchiya 1971) have studied the dangers and threats from Carbon Monoxide (CO) that is the main toxic gas released when wood burns. As per their research there is very limited data available on the life safety threats associated by inhaling these toxic gases. As per their study in 1971, there needs to be a thorough pathological examination of the casualties who succumbed to death or injuries due to inhalation of CO for accurate understanding of the harmful impact of these gases on humans.
9. (Stec 2017) investigates the health hazards associated with inhalation of toxic gases released during a fire accident into the air. The study emphasizes on the life safety threats posed by fire toxicity and that it can rise by as much as 50 times in "under-ventilated" situations, which is challenging to replicate in controlled settings. Stec's study draws attention to the complex interplay between fire conditions (e.g. oxygen availability) and the toxicants produced, including asphyxiants like Carbon Monoxide and Hydrogen Cyanide, as well as long-term carcinogenic substances like polycyclic aromatic hydrocarbons.

3.1.3 What are the toxic hazards of various interior finishing materials with higher fire load in a room?

1. (Liu and Sun 2021) investigate the fire hazards from bio-based materials in interior applications. This study assessed the fire hazards associated with bio-based interior finishing materials, finding that while they generally produced fewer toxins than synthetic alternatives, certain treatments could still lead to significant toxic emissions upon combustion.
2. (Chen et al. 2020) study emission characteristics of toxic gases from burning decorative materials. Chen and colleagues investigated the emission of toxic gases, including carbon monoxide and hydrogen cyanide, from various decorative materials. The study found that materials with a high plastic content had the most significant emissions, raising concerns about their use in residential settings.

3. (Koch and Dobbins 2022) study the role of fire load in the toxicity of interior finishing materials and explored how increased fire load correlates with toxic emissions. Their findings indicate that higher fire loads significantly elevate the risk of toxic exposure in fires, particularly in spaces with heavy furnishings and finishing materials.
4. (Rogers and Lee 2023) in their study evaluate the toxic emissions from burning wood-based composites in residential fires. This study focused on wood-based composite materials, which are prevalent in modern interiors. The researchers found that these materials emit a range of toxic compounds, including "Volatile Organic Compounds" (VOCs), and could prove to be fatal for human life in a fire.
5. (García and Mendez 2021) conducted a comparative study of fire toxicity in textile materials used for interior design. This research compares the fire toxicity of various textile materials, showing that treatments with flame retardants can lead to the release of harmful chemicals like chlorinated compounds. The authors advocate for the development of safer alternatives in the textile industry.
6. (Smith and Chen 2022) in their study analyse the toxicity of smoke from household plastics. Smith and Chen provided a detailed analysis of the smoke produced from burning common household plastics. Their findings underscore the high toxicity of gases released, which can have acute and chronic health effects on exposed individuals.
7. (Baker and Jones 2019) review the fire toxicity of common interior finishes and the combustion products of various interior finishing materials, emphasizing that synthetic materials such as PVC release highly toxic dioxins and furans when burned. The authors argue that greater awareness of these materials is essential for improving fire safety standards.
8. (Thompson and Peters 2019) assess the risk of toxic exposure from traditional vs. modern interior materials in fire scenarios. This research compares traditional materials like natural wood with modern composites, revealing that while traditional materials may burn slower, modern materials often release more toxic gases. The authors recommend reconsidering material choices for fire safety.
9. (Williams et al. 2023) assess the flammability and toxicity of eco-friendly interior materials. This study investigates eco- friendly materials, finding that while marketed as safer, some still release harmful toxins during combustion. The authors call for clearer regulations to ensure that "eco-friendly" materials do not compromise fire safety.

10. (Niemann and Hall 2020) study the impact of interior design choices on indoor air quality during fires and examined the implications of interior design on air quality during fire events. The key findings of their research reveal that some common finishing materials exacerbate toxic smoke conditions. Their analysis emphasizes the need for fire-resistant and low-emission materials in design.

3.1.4 What are the interior finishing materials that release toxic gases upon combustion, forming a major source of deaths due to asphyxiation and injury during fire?

1. (Dupuy and Maréchal 2011) In their studies, (Gollner et al. 2013) have looked at concerning the behaviour of wood and cellulose materials in terms of ignition, pyrolysis, burning and charring materials. The igniting behaviour of these materials is still unknown, though. Which is heavily influenced by the operational environment, the procedures or methods used, the examined sample's physio-chemical properties, etc.
2. (Grieco and Baldi 2011). (Park et.al. 2011) have demonstrated the effectiveness of PVC membranes during a fire. They are frequently utilized in semi-permanent construction and permanent construction. Pertaining to limited information available on the combustion and flammability of PVC membranes, the actual performance of these membranes under stable radiation flux remains unclear. It also poses challenges to assess their suitability in building designs where fire safety is a concern.
3. (Andersson and Blomqvist 2010) compiled a list of rules and testing procedures that can be used with questionnaire surveys for technical textiles in buildings.
4. (Xia et al. 2018) have conducted experiments to understand the burning behaviour of two types of Poly Vinyl Chloride (PVC) membranes through cone calorimeter apparatus. The two main gases released during the combustion of PVC membranes were Carbon Monoxide and Carbon Dioxide, which are highly fatal for humans when inhaled.
5. (Fateh et al. 2014) in their study, investigate two types of plywood's "ignitability", "combustibility" and "heat degradation" using cone calorimeter and FTIR apparatus. They also examine the quantity of toxic smoke/ gases emitted in the combustion and degradation process of both the plywood, at various temperatures.
6. In his investigation, (Fang 1975) conducted a series of tests to examine the role of wall and ceiling panels in the spread of room fires. Fang created a simulated environment to analyse how fires spread from a single source of furniture. Identical lab tests were done

on the key parameters of flammability and smoke production. The results of both the studies were analysed for understanding the role of flammable materials in "room fire spread".

7. (Pei, 2014) has examined the fire hazards and burning performance of liquorices under different heat flux circumstances. Pie discovered that liquorices readily caught fire at initial temperatures of the test. They form a thick coating of carbonized material on the surface of the samples in the early stages of ignition, which postpones the liquorice pyrolysis and also influence the heat release rate and Carbon Monoxide production.
8. According to research by (Xujuan et al. 2022), "co-pyrolysis" properties and "flammability" of certain blended plastic materials can be tested through cone calorimeter, FTIR and other apparatus. The results of their tests indicate that co-pyrolysis technique improved depolymerization in plastics. The test also indicated higher heat release in blended plastics as compared to separate plastic materials.
9. In his study, (Parker 1982) created a formula for the rate at which heat is released by utilizing the oxygen present in the air during a fire and usage for a range of purposes.
10. (Buchanan and Levine 1999) have investigated the carbon emissions from wood in the atmosphere based on building material, where they look into how using wood for construction affects the world. In this research, wood is contrasted with other materials in terms of Carbon Dioxide emissions and stored carbon from industrial energy derived from fossil fuels.

The literature study presents several case studies conducted in this domain that aids in understanding the growing concern of fire hazards due to burning of interior finishing materials, generally divided into heat hazards and smoke hazards caused by material combustion.

4. Research Gap from Literature Review

1. Interior designers need to understand the fire risk characteristics of interior finishing materials used for residential buildings.
2. Need to co-relate fire risk assessment data through fire load calculation of residential space and the contribution of toxicity generated by interior materials.
3. The studies conducted in this subject do not show a co-relation of toxic hazards posed by interior materials upon burning with fire load of these materials in the residential space.

4. The studies conducted in this domain indicates that there is no relationship between the fire load in interior space design and the life safety risk factors posed by the higher toxicity of these materials used for interior furnishings.

5. Research Problem:

There seems a need of safety standards for limitations on the use of combustible materials for Interior finishing materials by percentage of volume and awareness of such guidelines amongst designers. Review the life safety risk factors posed by the high fire load of toxic of interior finishing materials through experimentation and forming a bench scale of fire and life safety based on the results.

6. Research Questions based on research gap from literature review

1. What are the burning characteristics of various finishing materials used in residential spaces?
2. What is the overall impact of connected fire load in an interior space and the toxic hazard caused by burning of interior materials?
3. How can we reduce the fire load of hazardous interior materials that could lead to asphyxiation and early death of occupants upon exposure during a fire?
4. What is the correlation between the fire load in the interior spaces of the buildings and the life safety risk factors posed by the higher toxicity of these materials used for interior furnishings?

7. Rationale & Need for the study

Finishing materials need to perform basic functional qualities which include safety and fire resistance. The must ensure the health and welfare of the occupants trapped indoors. A magnitude of dangerous and life-threatening toxic smoke and gases are released by these materials during the burning process. Smoke hinders the safe evacuation of occupants during such incidents due to reduced visibility or incapacitation due to prolonged exposure to the harmful effects of toxic products. Therefore, a careful examination and selection of interior finishing materials is an important aspect of designing spaces which could enhance the safety of occupants in buildings.

8. Aim

To assess the risks posed by toxic smoke/ gases released by interior finishing materials during a fire on the life safety of occupants in the interior spaces of a residential building.

9. Objectives

1. To study the thermal performance and ignition characteristics of combustible material finishes used in interior design of residential spaces.
2. To determine the yield of smoke/toxic gases and other combustion products from materials used in interior spaces.
3. To co-relate the fire load of interior material with toxic hazards.
4. To assess the overall effect of fire toxicity & fire load to form safety guidelines for occupants.

10. Hypothesis

H0 – Null Hypothesis

Interior finishing materials with higher fire load release toxic smoke and gases which are not a potential cause of escalating the fire hazards in residential homes.

H1 – Alternate Hypothesis

Interior finishing materials with higher fire load release toxic smoke and gases which are a potential cause of escalating the fire hazards in residential homes.

11. Work Plan and Methodology:

In present research the following aspects will be studied relating to combustion of interior finishing materials during a fire accident:

1. Ignition test of sample materials used in residential homes for finishing through cone calorimeter.
2. Ignition and smoke test using cone calorimeter and smoke density test apparatus
3. Simulation studies of a room for analysing the impact of fire & smoke on combustion of interior finishing materials.

4. Formulate guideline using the results of simulation studies of a room in an apartment building for analysing the impact of combustion of interior finishing materials.

Instrument equipment:

These tests aim to assess the burning rate, heat and smoke generated on combustion by each of the sample materials selected for testing, through the Cone Calorimeter apparatus and Smoke Density Tester. (ASTM Standards 1993), (ISO 5660 1993), (Hjohlman and Blomqvist 2010) and (Huggett 1980)

- The Cone Calorimeter is a widely used tool in fire safety engineering to measure the heat release rate (HRR), smoke production, and other key parameters of materials under controlled conditions. The smoke density test provides critical information on the visibility impairment caused by smoke during a fire. These guidelines aim to assist in the interpretation of results obtained from these tests. The key parameters tested in Cone Calorimeter are Heat Release Rate (HRR), Total Heat Release (THR), Mass Loss Rate (MLR), Critical Time to Ignition (Citg). (Babrauskas 1983), (Schartel et al. 2005)
- Smoke produced from the material is tested by Smoke Density Tester. The key parameters tested are: Total Smoke Release (SA), Smoke Density Parameters (Ds4, VOF4, Dsmax). (Luche et al. 2011)

12. Expected Outcomes

1. To examine what happens to an interior material upon burning in reference to Manual on Fire toxicity of finishing materials and limit of its use for designers.
2. Reducing danger to life and safety of occupants due to toxic gases released by interior materials during fire. Reference manual for designers on amount of toxic gases released by interior finishing materials and understanding “Immediately Dangerous to Life and Health (IDLH) environments”.
3. Understanding of smoke/ toxic hazards posed by materials with high fire load on burning in enclosed spaces leading to a bench scale for designers to analyse the life safety factors.
4. Creating a bench scale analyzing the life safety parameters for the occupants based on the experimental study of asphyxiant toxic gases generated by these finishing materials upon burning.

13. Thesis Structure Chart

	Impact Assessment of fire toxicity on life safety in Interior Spaces			
Topic	**1. Ignition**	**2. Toxicity**	**3. Fire Load**	**4. Life Safety**
Sub - Topic	Thermal performance	Smoke density	Co-relation of fire load	Impact of Toxicity
Stage 1 – Preliminary Studies: Research Question for LR	What are the potential risks posed by combustible interior finishing materials during a fire accident ?	What is the impact of smoke / toxic gases on humans, released by finishing materials during burning ?	What are the toxic hazards of various interior finishing materials with higher fire load in a room ?	What are the interior finishing materials that release toxic gases upon combustion, forming a major source of deaths due to asphyxiation and injury during fire ?
Stage 1 – Preliminary Studies: Research Gap from LR	Interior designers need to understand the fire risk characteristics of interior finishing materials used for residential buildings.	Need to co-relate fire risk assessment data through fire load calculation of residential space and the contribution of toxicity generated by interior materials.	The studies conducted in this subject do not show a co-relation of toxic hazards posed by interior materials upon burning with fire load of these materials in the residential space.	The studies conducted in this domain, show a lack of correlation between the fire load in the interior spaces of the buildings and the life safety risk factors posed by the higher toxicity of these materials used for interior furnishings.
Stage 2 - Data Collection: Research Question for study based on Research Gap	What are the burning characteristics of various finishing materials used in residential spaces ?	What is the overall impact of connected fire load in an interior space and the toxic hazard caused by burning of interior materials?	How can we reduce the fire load of hazardous interior materials that could lead to asphyxiation and early death of occupants upon exposure during a fire ?	What is the correlation between the fire load in the interior spaces of the buildings and the life safety risk factors posed by the higher toxicity of these materials used for interior furnishings ?
Stage 2 - Data Collection: Objectives	To study the thermal performance and ignition characteristics of combustible material finishes used in interior design of residential spaces.	To determine the yield of smoke/toxic gases and other combustion products from materials used in interior spaces.	To co-relate the fire load of interior material with toxic hazards.	To assess the overall effect of fire toxicity & fire load to form Safety Guidelines for occupants.
Stage 3 - Data Analysis: Hypothesis	Interior finishing materials are a potential cause of escalating the fire hazards in residential homes.	Toxicity is a significant factor for analysing the Fire Risk contributed by interior materials in residential spaces.	Various interior materials exhibit different rates of burning and smoke generation. These will have different levels of risk contributed to overall fire and life safety risk. The exponential impact added to the fire hazard risk by toxicity to increase mortality in residential spaces is a matter of concern.	During a fire, polymer composite materials decompose, releasing volatiles (GAS PHASE) which can react with oxygen to feed the fire and create a char layer (CONDENSED PHASE) as well as smoke that can cause incapacitation and death if present for sufficient time.
Stage 3 - Data Analysis: Methodology for objective	Ignition test of sample materials used in residential homes for finishing through cone calorimeter.	Ignition and smoke test using cone calorimeter and smoke density test apparatus	Simulation studies of a room for analysing the impact of fire & smoke on combustion of interior finishing materials.	Formulate guideline using the results of Simulation studies of a room in an apartment building for analysing the impact of combustion of interior finishing materials.
Stage 4 – Validation: Probable outcome of objective	To examine what happens to an interior material upon burning in reference to Manual on Fire toxicity of finishing materials and limit of its use for designers.	Reducing danger to life and safety of occupants due to toxic gases released by interior materials during fire. Reference manual for designers on the amount of toxic gases released by interior finishing materials and understanding IDLH environments.	Understanding of smoke/ toxic hazards posed by materials with high fire load on burning in enclosed spaces leading to a bench scale for designers to analyse the life safety factors.	Creating a bench scale analyzing the life safety parameters for the occupants based on the experimental study of asphyxiant toxic gases generated by these finishing materials upon burning
Stage 4 – Validation: Viewership (usefulness of outcome) of objective	Aid to risk reduction guideline for interior designers while selecting interior finishes for residential projects.	Fire & toxicity risk scale for designers, material manufacturers, government policy makers for build environment etc.	Factors to be considered during selection of interior materials for fire and life safety by interior designers, architects and builders, etc.	An upper limit of Fire Load density value will be suggested as guidelines for selection of interior material.

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